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Multiple marine ecological disturbance assessments for latin american and caribbean large marine ecosystems

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ABSTRACT

Comparative assessment of pollution and ecosystem health among the Large Marine Ecosystems (LMEs) of Latin America and the Caribbean requires tracking of shifting food- chain associations, loss of habitat, toxic and anoxic impacts to species, diseases, harmful algal blooms and vulnerability to climate extremes, invasive species, and overfishing. Meta-data search and extraction techniques help researchers consolidate disturbance observations into one of eight multiple marine disturbance (MMED) categories important for the creation of place specific disturbance regimes. By measuring the changing baseline condition of impact-sensitive indicator species involved in these MMED events, resource managers can better compare, mitigate, and track changes in marine ecosystem health.

1. Multiple marine ecological disturbances

Healthy co-evolved plants, wildlife, and human interdependent systems can recover from short-term disturbance events. Conversely, when marine ecosystems are impacted by pollution, disease, habitat loss, repeated climate extremes, invasive species, harmful species and extirpation of key species, these systems lose their self-regulatory function and may no longer recycle nutrients to sustain anticipated production levels. Impacted ecosystems become brittle in the face of disturbance and susceptible to dramatic shifts (state change) in biotic community structure from dominance by relatively large, long-lived native species to dominance by smaller short-lived exotics (Holling, 1995). Throughout the 10 Latin America and the Caribbean Large Marine Ecosystems (LMEs), resource managers are finding statistical correlations between brittle marine ecosystems as described and those perceived to be most health impaired (HEED, 1998, Sherman, 2000). Documentary evidence within the academic literature of oil spills from the late 1960s and early 1970s, harmful algal blooms (HABs) from the mid-1970s, coral system collapses from multiple marine ecological disturbances (MMEDs) during the late 1980s, and beach closures and human marine-related illness in the 1990s describe various assemblies of sentinel species that appear representative of health status for specific locations.

Marine disturbance events, defined as anomalies, are described as such because they are unanticipated. While portions of the phenomena driving marine structural and functional change may be captured and described by epidemiologists, resource economists, climate and marine scientists, no single discipline's information network can entirely characterize widespread spatial and unprecedented temporal characteristics of these events because disciplinary health status and trends monitoring programs are full of data gaps or non-existent within the developing world. Ample observational information does exist for which location status and trend can be re-assembled to fill information gaps, however observations are scattered among a multitude of custodians and reporting forms; effectively lost. Scientists have been performing meta-analysis to reassemble information by-products of a century's worth of fragmented time-series studies, critical for establishing marine health baselines in specific locations (LTER, 1992, NRC 1990). These baseline studies are important for reference. However, to perform a comparable task at an LME scale, ≥200,000 sq

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km, special data assembly techniques are required to re-acquire lost observations. Classification techniques that characterize MMED phenomena, an acronym coined for this purpose at a Caribbean conference (Williams and Bunkley-Williams, 1990a, 1990b, 1992), operate at scales relevant to the Latin American and the Caribbean LME projects, and have since been systematized into a discipline unifying methodology (Epstein et al., 1998; Sherman, 1999) that better describes marine health status among all LMEs (Sherman, 2000).

It has been left to data-scientists to pull together comparable characterizations of anomalies to answer a simple question for each recovered piece of data: "is this observation ordinary or extra-ordinary for a given place and time?" Ultimate determination requires hind-casting against other available time-series (e.g. satellite, ship-born surveys, fisheries statistics, and weather gauge networks). To begin a data archaeologist may focus on meta-data (data about data) and extract this information from bibliographic archives using keyword searches. Then, efforts can focus on the appropriate acquisition of the primary data itself. Anomaly or disturbance is a concept uniquely shared by all disciplines and is exploited to unify thematic data by describing phenomena involving multiple oceanographic, ecological and economic indicators. The spatio/temporal scale of an observational data point presents an opportunity to unify diverse anomaly data sources from any number of other disciplines provided the quality and time-structured data reside within a geographic information system's database.

2. Disturbance as a device

In the Humboldt Current LME, dramatic changes in Peruvian anchoveta and sardine fisheries were not always understood to be associated with ENSO cycles (Polovina et al., 1995). Like other disturbance studies (Pimm, 1984; Holling, 1995; Rapport, 1995; Karr, 1991; Costanza, 1992; Costanza et al., 1992; Likens, 1992; Rapport et al., 1985) the term "disturbance" is useful until perceptions of "normal" ecosystem processes change with respect to either widespread acceptance of re-defined recurring processes or when historical records reveal normal periodicity; rendering new observations as expected. In fact, the term *anomaly* is common to all disciplines (cultures) and exploration and is useful as long as we seek more perfect insights. In the marine environment there is ample opportunity for multi-data syntheses because morbidity and mortality observations (a disturbance byproduct) are plentiful, a normal part of field research description and typically guide taxonomic data collection strategies. Walking a beach, performing a bird survey in the field, observing diseased or out-of-place specimens; disturbance problems lead to the same sets of questions regardless of geography: why do marine mammals strand? when will harmful algae blooms re-occur? where will fish and invertebrate diseases move next? Pursuit of these questions is limited if only single species are tracked. Disturbance phenomena acting over wide-geographies have properties that alter multiple species activities, environments and economies. A single species indicator may not touch all of the scales necessary to understand larger disturbance patterns. Larger questions encompassing ecosystem phenomena including: cascading system collapse (Jackson et al., 2001), biogeochemical cycling (USGCRP, 2000), disturbance conditioning (Sherman, 2001), pathogen pollution (Daszak et al., 2001), require multi-species approaches. Moreover, "multi-indicators" (not just species) may be used to capture events impacting many parts of a food chain (e.g. fish consumption advisories plus human illness) and provide a rationale to use one indicator as a replacement (proxy) for another (e.g. mouse lethal dose toxicity studies for harmful algae concentrations and bloom duration). Ultimately, enough proxy data can be pooled so that all scales (set by the natural history of organisms, or measurement technique) may blend to visualize an emergent phenomenon/pattern.

Researchers have long argued agency mandates and priorities need to capture both ecological and economic factors aligned with disturbance, not only because society would better understand extractive/consumptive relationships, but to better highlight significant and persistent pressure upon the tipping-points for sustainability within those same ecosystems (Holling, 1995; Epstein, 1996; Epstein and Rapport, 1996). External climate forcing on charismatic keystone species has been popularized among most LMEs as climate variability is universal and strategic selection of multiple-indicator organisms in the keystone specie's habitat can integrate across all of the necessary scales of observation (Ebbesmeyer et al., 1991; McGowan et al., 1998).

3. Data discovery and recovery operations

Society has invested in disturbance studies, however, the tangible outlet is not raw cross-region compatible data, but rather, individual peer-reviewed publications describing segments of phenomena (a typical grantor's expectation for incremental research). A recovery strategy designed to consolidate ecosystem health disturbance knowledge comes from surveys the published results of each funded organism study in bibliographic reference collections, using spatial, temporal and anomaly keywords to unify disciplines. The benefit of this inductive investigative process is to facilitate shifts from space/time questions viewed by some academic communities as uninteresting to phenomena-based questions of keen interest to the public (Sherman and Epstein, 2001). Review studies implementing such data discovery techniques (HEED, 1998, Fisher et al., 1999, Sherman, 2000) provide the research and management community with effective means to reduce data overburden and maximize information distillation (Christensen et al., 1996).

4. Methodology for MMED indicator selection

A disturbance indicator approach was implemented as part of the Health Ecological and Economic Dimensions of Global Change Program's Multiple Marine Ecological Disturbance project (HEED MMEDs) based at Harvard University and Harvard Medical School. The project involved more than 250 academic marine resource and science professionals in an assessment of morbidity, mortality and disease events along the eastern coast of North America, the Gulf of Mexico, and the Caribbean Sea ecosystems (a